The World Energy Projection System Plus (WEPS+): Global Activity Module

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Update Information

This edition of the Global Activity Module (GAM) – Model Documentation 2013 reflects changes made to the GAM over the past year for the International Energy Outlook 2013. These changes include:

- Exogenous assumptions of economic activity for IEO regions have been replaced by forecasts based on the economic and industrial models of Oxford Economics.

Update Information

Introduction

The World Energy Projection System Plus (WEPS+) is a comprehensive, mid-term energy forecasting and policy analysis tool used by the EIA. WEPS+ projects energy supply, demand, and prices by country or region, given assumptions about the state of various economies, international energy markets, and energy policies. The Global Activity Module (GAM) provides projections of economic driver variables for use by the supply, demand, and conversion modules of WEPS+. The GAM's baseline economic projection contains the economic assumptions used in WEPS+ to help determine energy demand and supply. The GAM can also provide WEPS+ with alternative economic assumptions representing a range of uncertainty about economic growth. The resulting economic impacts of such assumptions are inputs to the remaining supply and demand modules of WEPS+.

This report documents the analytical approach of the GAM that is used to develop the *International Energy Outlook for 2013* (*IEO2013*). It serves as a reference document providing a description of the GAM used for the IEO2013 production runs for model analysts, users, and the public. It also facilitates continuity in model development by providing documentation from which energy analysts can undertake model enhancement and modifications. This documentation report is divided into two separate components.

Section 2 presents the structural models comprising the GAM. These include:

1. Oxford Economics Global Economic Model (GEM); and
2. Oxford Economics Global Industrial Model (GIM)

Section 3 focuses on the GAM's interface with WEPS+. This section identifies the set of model levers and simulation rules used to operate the system. This section also views the GAM from the perspective of a programmer focusing on the ties that link the various models together to form the GAM and how the GAM communicates with WEPS+.

Model archival citation

This documentation refers to the WEPS+ Global Activity Module, as archived for the International Energy Outlook 2013 (IEO2013).

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Modeling System Overview

Economic activity driving WEPS+ is determined by an economic modeling system comprised of two models:

1. Oxford Economics Global Economic Model (GEM); and
2. Oxford Economics Global Industrial Model (GIM).

Oxford Economics model of the global economy is the same model used by the firm to produce its economic forecasts for the company's monthly assessment of the global economy. The particular GEM model used for the IEO 2013 is the October 2012 version. Oxford Economics GIM model provides the industrial output detail required by the WEPS+ modeling system. The particular GIM model used for the IEO2013 is the Q4 2012 version. The GAM models are linked to provide a fully integrated approach to estimating economic activity at the country/regional and industrial levels.

Oxford Economics model of the global economy models each national economy's growth path and the final demand mix. The global industrial model ensures that supply by industry is consistent with the final demands (consumption, investment, government spending, exports and imports) calculated in the GEM model. Together, these models of the global economy and global industrial output constitute the Global Activity Module (GAM) of the World Energy Projection System Plus (WEPS+).

Before the GAM can execute its suite of models though, it requires exogenous assumptions regarding energy prices and quantities. In the current version, both oil and natural gas prices are extracted from the output of the demand and supply modules of WEPS+. Transformations of the exogenous assumptions are necessary to map these inputs from WEPS+ into more aggregated concepts in the GAM. After the appropriate transformations are done, the GEM and GIM execute in sequence to produce an estimate of economic activity at the national and industrial levels. Drawn from the projections are economic driver variables that are then passed to the supply, demand and conversion modules of WEPS+, and the system is able to react to the new economic activity assumptions.

Oxford economics global economic model

Key Inputs: National population by age cohort, total factor productivity, tax rates and nominal expenditures, money supply, and energy prices and quantities.

Key Outputs: Final demands (consumption, investment, government purchases, exports, imports), inflation, foreign exchange and interest rates, incomes, employment, and balance of payments.

Overview

The Oxford Economics Global Economic Model (GEM) is an international macroeconometric model which covers 76 countries and six additional regions and forecasts numerous variables through 2040. The individual countries are modelled similarly, but larger economies have greater disaggregation and more financial sector detail. All of the countries have forecasts for GDP, consumer prices, exchange rates, and the current account. Each of the countries and regions are fully linked through trade, prices, exchange rates, and interest rates.

The structure of each country and region in the GEM is based on standard economic theory. In the long-run population growth and productivity drive economic activity, but there are fluctuations in the short-run associated with business cycles. These business cycles arise from a number of factors, including wages and prices that do not adjust over short periods, non-competitive behavior by firms, and various regulations, to name a few.

The long-run price level depends on monetary policy, which has no impact on economic activity over this time-horizon. Monetary policy does, however, have a short-run impact on output, although this will also influence the price level.

Consumption in each country or region depends upon income, wealth, interest rates, and inflation. Investment varies based on its risk-adjusted after-tax return, while exports are a function of world demand and the real exchange rate. Imports are determined by domestic demand and competitiveness.

Coverage of the oxford model

The GEM covers 44 countries in depth and provides high-level details for another 33. Global coverage is completed with another six regional groupings. Countries covered in detail:

Table 1. Oxford GEM country coverage

Argentina	Japan
Australia	Malaysia
Austria	Mexico
Belgium	Netherlands
Brazil	Norway
Bulgaria	Philippines
Canada	Poland
Chile	Portugal
China	Romania
Croatia	Russia
Czech Republic	Singapore
Denmark	Slovakia
Finland	South Africa
France	South Korea
Germany	Spain
Greece	Sweden
Hong Kong	Switzerland
Hungary	Taiwan
India	Thailand
Indonesia	Turkey
Ireland	UK
Italy	US

Other countries covered in the regions:

Table 2. Oxford GEM regional coverage

Rest of the OECD	OPEC	Eastern Europe	Africa	Latin America	Rest of World
Iceland	Algeria	Kazakhstan	Cameroon	Bolivia	Bangladesh
Luxembourg	Iran	Ukraine	Egypt	Colombia	Israel
New Zealand	Iraq		Kenya	Costa Rica	Myanmar
	Nigeria		Morocco	Dominican Republic	Pakistan
	Saudi Arabia		Sudan	Ecuador	Syria
	Venezuela		Tunisia	Panama	Vietnam
			Uganda	Paraguay	
				Peru	
				Uruguay	

The model also includes global and multi-region variables such as oil and commodity prices, world GDP and industrial production, OECD average inflation, and others.

Each of these countries and regions are mapped into the 16 IEO regions:

Table 3. Regional coverage of the world energy projection system plus model

OECD Regions	Non-OECD Regions
United States	Russia
Canada	Other Non-OECD Europe and Eurasia
Mexico/Chile	China
OECD Europe	India
Japan	Other Non-OECD Asia
Australia/New Zealand	Middle East
South Korea	Africa
	Brazil
	Other Central and South America

Detailed model structure

Model variables are divided into demand and supply, core and non-core. Coverage of core variables is standard across all country models; non-core coverage is determined by data availability and country-specific requirements. Core demand variables include all the aggregate expenditure components, at constant and current prices, monetary policy variables, and financial variables. The demand non-core

includes disaggregated consumption and investment, as well as important indicator variables such as retail sales and car sales. Core supply consists of variables determining the levels of output, unemployment, and real wages. Prices are also disaggregated in the core supply block. Non-core supply disaggregates employment and nominal earnings. Separate blocks build up the government, personal and corporate sector flow accounts.

The model variables are all in units of local currency for the country under consideration (the majority), unit-less rates, or ratios that also do not have units. Lowercase variables denote natural logarithms in the equations below. The data sets used in estimating the model parameters also vary by country.

Consumption

The model equations for consumption take the form:

$$\Delta c_t = a_1 \Delta y_t + a_2 \Delta u_t - a_3[c_{t-1} - a_4 y_{t-1} - (1 - a_4)W_{t-1} + a_5 R_{t-1}],$$

where $\Delta x = x_t - x_{t-1}$, for all variables x;

c_t = natural logarithm of consumption during year t;

y_t = natural logarithm of real income during year t;

u_t = natural logarithm of unemployment rate during year t;

W_t = ratio of financial wealth to income during year t;

R_t = real interest rate during year t.

This formulation mimics the dynamics of consumption in a number of countries well.

Investment

Three aspects of gross fixed investment are identified in the model: private business, private housing, and government (exogenous).

The equations for business investment are based on standard theories of investment. The capital stock is assumed to reach its desired level in the long run, while fluctuating in the short run. These fluctuations occur because capital installation is costly and time-consuming, which means there is a difference between the benefit of an installed unit of capital and its cost. Firms invest when this benefit exceeds the cost, and reduce or scrap capital in the reverse case. The equations take the following general form:

$$\Delta i = a_1 q_t - a_2(i_{t-1} - k_{t-1}) + a_3 \Delta y_t,$$

where i_t = private sector business fixed investment during year t;

k_t = specific type of capital stock during year t;

y_t = real GDP during year t;

q_t = benefit of installed capital relative to its cost (real interest rate) during year t.

This mechanism can also amplify changes in the economy as firms may reduce or increase investment, because the value of q_t changes.

Personal sector housing investment is estimated analogously to consumption, by real income, wealth, and interest rates, since it is considered part of a portfolio of spending decisions taken by households.

International trade

Trade flows are disaggregated into fuel, non-fuel goods, and services. The non-fuel goods components reflect the majority of exports and imports for most countries and these are outlined here. Exports and imports are specified as:

$$\Delta x_t = \Delta wt_t - a_1 cu_t - a_2 \Delta wcr_t - a_3(x_{t-1} - wt_{t-1} - a_4 trx_t),$$

$$\Delta m_t = b_1 \Delta tfe_t + b_2 \Delta wcr_t - b_3(m_{t-1} - tfe_{t-1} - b_4 wcr_{t-1} - b_5 cu_{t-1}),$$

where x_t = exports of non-fuel goods during year t;
m_t = imports of non-fuel goods during year t;
wt_t = world trade during year t;
tfe_t = total final expenditure during year t;
wcr_t = labor costs in a country relative to its trading partners during year t;
cu_t = capacity utilization rate during year t;
trx_t = exogenous time trend during year t;

The parameters in the equations above capture the effects of non-price factors on a country's world trade share, as well as the impacts of the long-term increase in the specialization of production on imports. In general, a sustained decline in relative labor costs (an improvement in competitiveness) leads to an improvement in the trade balance in the long run.

The equations for trade in services are analogous to those for non-fuel goods, while fuel trade is calculated as the residual.

Linkages between economies

The Model links the individual countries in a number of ways

- Trade
- Labor costs in a country relative to trading partners (competitiveness)
- Interest and exchange rates
- Oil and other commodity prices
- Prices of manufactured goods

Oxford economics global industrial model

Key inputs: Final demands, prices and productivity measures from Oxford Economics model of the global economy.

Key outputs: Real output value (defined by gross output) for both industrial and service sectors.

Overview

The global industry model has a top-down structure with sector forecasts driven national trends and by aggregate demand from three regional blocs: the Americas; Asia Pacific and Europe; and Middle East and Africa. Sector demands from the three blocs are allocated to individual industries using weights based upon regional input-output relationships. These relationships – derived from national input-output tables – show the percentage of each industry's output that is driven by: consumer expenditure, investment, exports, government spending, and intermediate demand.

The model also takes into account the impacts of changes in competitiveness on an industry's market share both regionally and nationally. Industry classification follows the European standard classification structure (Nomenclature Statistique des Activités Economiques dans la Communauté Européenne revision 2, NACE 2). There are eight headline manufacturing sectors: basic metals; chemicals; aerospace; intermediate goods; engineering and metal goods; electronics and computers; motor vehicles; and consumer goods. These are further broken down into subsectors, as follows:

- Basic metals: Iron and steel, non-ferrous metals, casting
- Chemicals: Coke, petroleum and nuclear fuel, chemicals and man-made fibres, basic chemicals, excluding agro-chemicals, agro-chemicals, paints and varnishes, pharmaceuticals, soaps and detergents, other chemicals, man-made fibres
- Aerospace
- Intermediate goods: Rubber and plastics, glass, ceramics, bricks, cement, and plaster, wood and wood products, pulp and paper
- Engineering and metal goods: Motors, generators and transformers, electric fittings, other electrical equipment, motors except for vehicles, other general purpose machinery, agricultural machinery, machine tools, other special purpose machinery, weapons and ammunition, domestic appliances
- Electronics and computers: Computers and office equipment, electronic components, telecommunications equipment, consumer electronics, precision and optical instruments

- Motor vehicles: Motor vehicles, motor vehicle bodies and parts
- Consumer goods: Food, beverages and tobacco, textiles, garments, leather goods, printing and publishing, other manufacturing, furniture.

Other production sectors include agriculture; extraction; utilities; and construction. In addition, the service sector covers the following subsectors:

- Retail and wholesale distribution
- Accommodation and catering
- Transport and storage
- Information and communications
- Financial services
- Business services
- Public administration services
- Education services
- Health care and social work
- Other services
- The industry model also provides forecasts of other variables such as:
- Value-added output and gross output across all industries and countries
- Producer prices across all industries for the UK, Germany, France Italy, Japan, US and China
- Employment and real/nominal investment across all industries for the UK
- Car/truck registrations and number of vehicles on road for 44+ countries
- Steel production for 11 countries (Belgium, China, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, UK, US)
- In process of adding investment across all industries for all countries.

The industrial sectors are aggregated as shown in Table 4.

Table 4. Industry sector mappings

WEPS+ Sector Name	ISIC Code	ISIC Description
Food	D15-D16	Food and Beverages; Tobacco Products
Paper and Pulp	D21-D22	Paper and Pulp; Printing and Publishing
Chemicals	D24	Total Chemicals
Chemicals	D25	Rubber and Plastics Products
Refining	D23	Refinery and Other Trans.
Iron and Steel	D27A	Iron and Steel
Non-ferrous Metals	D27B	Non-Ferrous Metals
Non-metal Minerals	D269C	Cement, Concrete, and Lime
All Other	A-B	Agriculture
All Other	C	Mining
All Other	D17-D19	Textiles and Apparel
All Other	D20	Wood Products, non-Furniture
All Other	D26-D269C	Mineral Base, ex. Cement
All Other	D28	Fabricated Metal Products
All Other	D30-D33	Electrical, Computers; Electrical, Other
All Other	D29	Machinery and Equipment
All Other	D34-D35	Motor Vehicles and Prods; Transport non-MV
All Other	D36	Furniture, Jewelry, etc.
All Other	F	Construction
All Other	D37	Recycling

The GAM Interface with WEPS+

The GAM provides macroeconomic projections for use by the other models in the WEPS+ system. The four projection series that it currently provides are:

- Gross Domestic Product (GDP) by region, expressed in purchasing power parity (PPP)
- GDP by region, expressed in market exchange rates (MER)
- Population by region
- Gross output by region and economic sector

The GAM is first made consistent with EIA energy prices and then run. The updated results are then exported into the WEPS+ restart file for use by other models (Table 5).

GAM Output	Destination
Gross domestic product (PPP)	Residential Model
	Commercial Model
	World Industrial Model
	International Transportation Model
	World Electricity Model
Population	International Transportation Model
Gross output	World Industrial Model

Relationship to other models

The GAM is an important component of the WEPS+ system. A summary description of the models, flows, and mechanics of the WEPS+ system used for the *IEO2013* report is available in a separate Overview documentation.

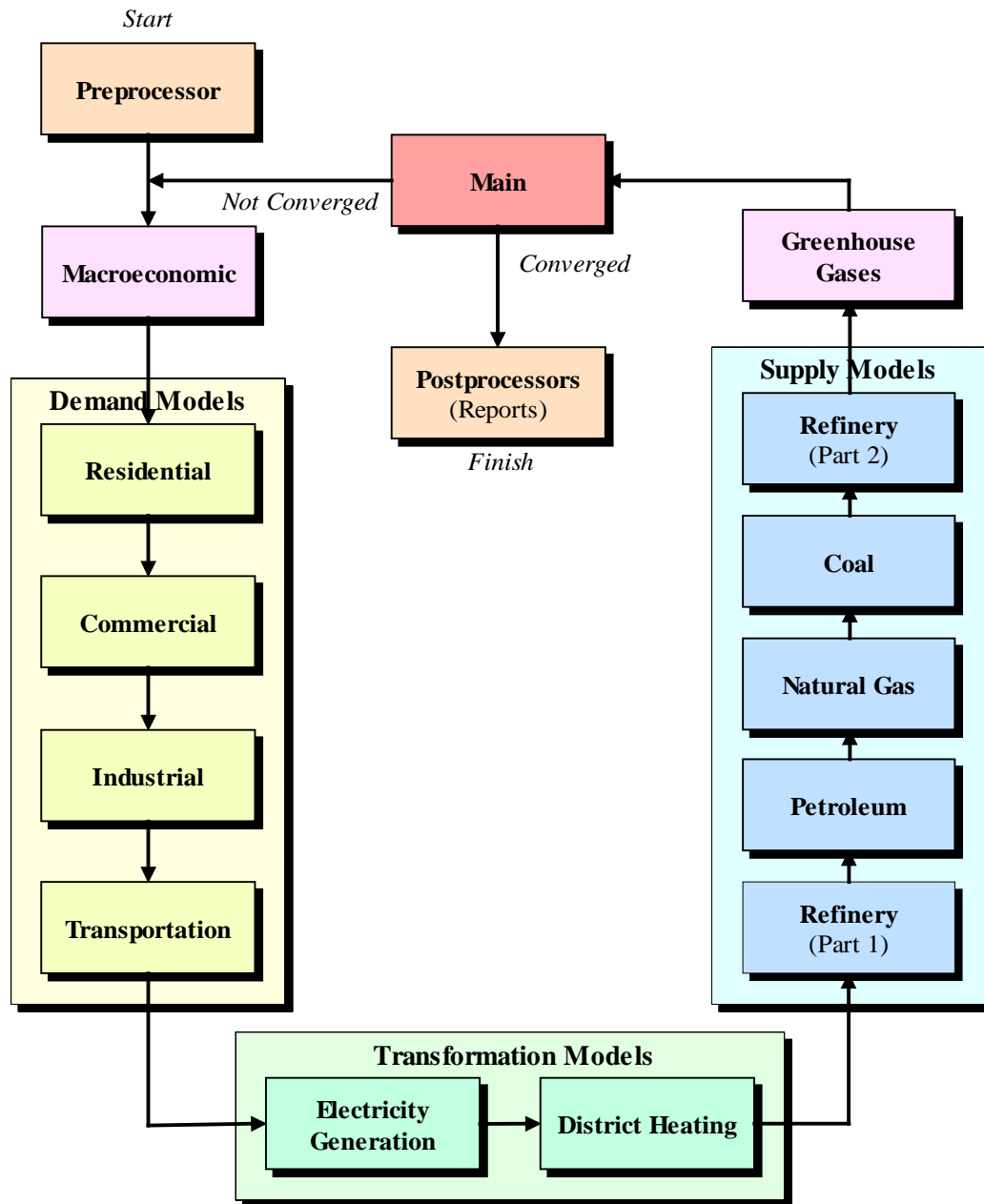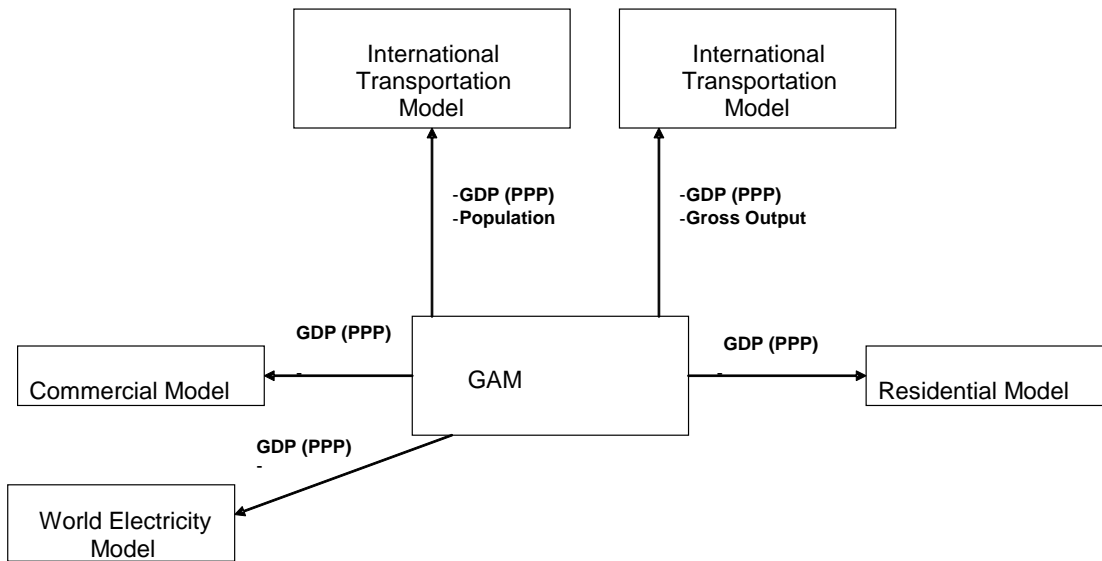**Figure 1. World Energy Projection System Plus (WEPS+) Model Sequence**

Figure 2. The GAM relationship to other WEPS+ models

The basic structure of the GAM is illustrated in Figure 3. A call from the WEPS+ interface to the GAM opens the restart file and initiates the CalcGDP subroutine. The CalcGDP subroutine gets results of GAM simulations before the execution of the subroutine that exports all projections to the restart file for use by other WEPS+ models.

The CalcGDP subroutine is initiated by a call from the main GAM. The model requires four exogenous data series. The CalcGDP subroutine begins by initiating a call of the XMLInput subroutine to import data from the MacInput.xml data file. The MacInput.xml includes historical and projected GDP data, by region, in terms of both purchasing power parity and market exchange rate, and historical and projected population each of which are based on GAM simulations. The file also contains several other elements such as energy prices and quantities. The GAM exports the data series to the restart file, and these are then used in subsequent runs.

Figure 3. Flowchart for the Global Activity Module